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Sufco Mine
A Subsidiary of Arch Western Bituminous Group, LLC.

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August 31, 2006

Coal Regulatory Program
Attn.: Pam Grubaugh-Littig
Utah Division of Oil, Gas and Mining
1594 West North Temple, Suite 1210
P. O. Box 145801
Salt Lake City, Utah 84114-5801

C/041/0002

Re: 2005 Annual Report Macroinvertibrate Study, Canyon Fuel Company, LLC, SUFCO Mine C/041/002

Dear Ms. Grubaugh-Littig:

Please replace the macroinvertibrate explanation page in the Sufco Mine 2005 Annual Report, Appendix B, with the enclosed macroinvertibrate study report. This study report 'An Assessment of the Macroinvertebrates of Box Canyon, Sevier County, Utah in October 2005' was recently completed by our consultant.

If you have any questions please give me a call at (435) 286-4421.

Sincerely,
CANYON FUEL COMPANY, LLC
SUFCO Mine

Michael L. Davis

Michael L. Davis,
Environmental Engineer

Enclosures

cc: Division of Oil, Gas and Mining – Price Field Office

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AN ASSESSMENT OF THE MACROINVERTEBRATES OF BOX CANYON, SEVIER COUNTY, UTAH, OCTOBER, 2005

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INTRODUCTION

This is a continuation of the monitoring of the Box Canyon drainage on the Southeastern Wasatch Plateau, Sevier County, Utah. This system is a tributary to Muddy Creek and the Fremont River of the Colorado River drainage. Box Canyon Creek heads at an elevation of approximately 2,600 meters above sea level. Mining induced subsidence occurred under the East Fork of Box Canyon in the late fall of 2003. Baseline samples of the invertebrate communities in the East Fork of Box Canyon were collected prior to subsidence on October 20, 2003. At the same time, the main stem of Box Canyon Creek (which we will designate as the Main Fork Box Canyon) was sampled to establish a control where no subsidence was expected. A second set of samples, post subsidence, was collected on October 3, 2004, and a third sample series was taken on October 8, 2005. The results from this third sampling effort are covered in this report.

METHODS

The control reach in the Main Fork of Box Canyon has been discussed previously (Shiozawa and Kauwe 2006). Its lower gradient and retention of organic matter resulted in it supporting a different community than that found in the East Fork of Box Canyon. During the 2005 sampling period, the streambed at the Main Fork Box Canyon was again retaining a high volume of leaf litter mostly from aspen.

The East Fork of Box Canyon streambed consisted predominantly of a mobile sand bottom with sections of exposed bedrock. Short plunge pools developed where the stream had downcut through Castlegate Sandstone to shales at the top of the underlying Blackhawk Formation. The plunge pools had bedrock or sand bottoms, but at the outflow of the larger plunge pools, gravel and rubble had accumulated. These were deposited during high flow events as the water exiting the plunge pools slowed (turbulence diminished) below the fall velocity for coarse particles. Since sand continued to be transported during lower flows, the outflow riffles became embedded in a sand matrix.

Because the different habitat types in the East Fork of Box Canyon would support different invertebrate communities, random or systematic sampling would result in multiple community types being collected and that in turn would generate high variability in the data being collected. This is the reason that the sampling was focused on riffles at the outflow of the plunge pools. In addition, riffle habitat is the one most likely to contain a diverse invertebrate assemblage. Since the invertebrates in riffles are in a region of moderate flows and turbulence, the riffle communities also include those taxa that require higher oxygen levels.

Sampling in the East Fork of Box Canyon began in the downstream-most station (Site 1). We progressively sampled upstream where adequate plunge pool/riffle habitats were found (Table 1).

Table 1. Sampling Station Locations

	Station	Station Code	Zone	East	North
Main Fork of Box Creek	Site 1	SBXM01	Z12S	E 0469490	N 4316829
East Fork of Box Creek	Site 1	SEFM01	Z12S	E 0471321	N 4317506
East Fork of Box Creek	Site 2	SEFM02	Z12S		
East Fork of Box Creek	Site 3	SEFM03	Z12S	E 0471336	N 4317420
East Fork of Box Creek	Site 4	SEFM04	Z12S	E 0471333	N4317378

Conductivity, pH, alkalinity, and hardness were measured to characterize the stations. Three samples were taken at each site. Since the data are being used to monitor changes in the stream over time, each site in the East Fork of Box Canyon is being treated as a replicate. The individual samples taken from within each site are, therefore, subsamples which give estimates of the density at the individual site (Jordan et al 1999). Thus, the samples were bulked together in the field. A modified Surber-type sampler based on the dimensions of the box sampler developed by Shiozawa (1986), with a net mesh of 250 microns, was used to collect the samples. The substrate was stirred to a depth of approximately five cm. All rocks within the area of the sampler were removed and individually washed to insure quantitative collection of the invertebrates. The samples were concentrated on a screen with a mesh of 64 microns and field preserved in ethyl alcohol. A GPS unit was used to both locate and record the positions of the sample stations which were also marked with plastic flagging.

In the laboratory, the samples were sorted in illuminated pans. All invertebrates were removed and identified to the lowest possible taxonomic level using the keys of Merritt and Cummins (1996). We took subsamples from the samples after they were visually sorted. The remaining sample material was placed in a beaker with a total volume of 200 ml and five 2 ml subsamples were removed and processed under magnification with a dissecting microscope. The mean density per subsample was used to estimate the total density of organisms remaining in the sample after it had been visually sorted. These projections were added to the total count from the visual sorting. The data were then used to determine the density of taxa per square meter. Mean biomass estimates were also generated so that trends in standing crop could be documented.

RESULTS AND DISCUSSION

Water Chemistry

In 2005, the Main Fork of Box Canyon Creek still differed from the East Fork of Box Canyon Creek in pH, alkalinity, and hardness being lower in all three parameters. However, the conductivity in the Main Fork of Box Canyon Creek had increased to the same range that had been recorded in three of the East Fork stations in 2004. Station 1 of the East Fork also increased in conductivity to the same range as the other stations (Table 2).

Alkalinity in the Main Fork, as in 2004, remained about one-third of that in the East Fork, but hardness in the Main Fork increased slightly, while it decreased slightly in most of the East Fork sites. As with the previous two sample periods, alkalinity was less than hardness indicating that other anions were present (Boyd 1990). In the two streams, it is probable that the difference is made up by sulfate ions. Assuming that the majority of the missing anions were sulfates and that the these were largely tied to divalent cations, the 2005 Main Fork sulfate levels were probably in the range of about 80 mg/l, similar to 2003 when the estimate was 86 mg/l. This is up from the 40 mg/l estimated in 2004. The East Fork sulfate levels were between 40 to 60 mg/l in 2005 with the exception of Station 2. The East Fork stations had approximately 40 mg/l in 2003, but in 2004, the sulfate levels varied from about 40 mg/l in the upstream station (Site 4) to 0 mg/l in the downstream most station (Site 1). The equivalent alkalinity and hardness values at Site 1 in 2004 were thought to be a result of changes in groundwater flow through a slump that developed at the lower end of Station 2. However, by 2005, both alkalinity and hardness had increased at this station from 40 to 70 mg/l .

In 2005, Station 2, alkalinity exceeded hardness by 60 mg/l. In this case, carbonates were in higher concentration than the measurable cations. This suggests that monovalent cations, which are not detected in hardness tests, are involved in the difference. If so, an increase in sodium or potassium is possible. All East Fork stations, except Station 2, showed a decrease in alkalinity from 2004 to 2005. The decline appears to be going back toward the 2003 levels. Hardness had the same pattern, with the exception of Station 1, where it increased.

Conductivity in both the Main Fork of Box Canyon and Station 1 in the East Fork of Box Canyon increased to levels similar to those recorded in Stations 2 through 4 on the East Fork of Box Canyon in 2004. Conductivity in Stations 2 through 4 remained about the same as their 2004 levels. All stations had higher conductivity readings than in 2003. Conductivity in 2005 increased progressively downstream (Stations 4 to 1, respectively) as would be expected. This is a change for the 2004 data at Station 1 where the conductivity was much lower than at the other stations. The pH readings have stayed relatively consistent throughout the three-year study period. The Main Fork of Box Canyon did have a decrease in pH from 7.8 to 7.3. It is still clearly more acidic than the East Fork sites, and the decrease in pH could be a function of increased flow (dilution) or increased leaching of pyrite deposits.

Table 2. Water Chemistry

Box Canyon Water Chemistry		Conductivity (uS/cm)	pH	Alkalinity mg/L $CaCO_3$	Hardness mg/L $CaCO_3$
Main Fork Box Canyon	October 2003	170	7.83	34	120
	October 2004	202	7.76	80	120
	October 2005	**412**	**7.3**	**60**	**140**
East Fork Box Canyon Site 1	October 2003	300	8.52	154	188
	October 2004	260	8.28	240	240
	October 2005	**463**	**8.42**	**200**	**260**
East Fork Box Canyon Site 2	October 2003	270	8.39	137	188
	October 2004	435	8.31	220	240
	October 2005	**432**	**8.3**	**260**	**200**
East Fork Box Canyon Site 3	October 2003	290	8.43	137	171
	October 2004	445	8.06	240	260
	October 2005	**426**	**8.3**	**180**	**220**
East Fork Box Canyon Site 4	October 2003	280	8.44	154	188
	October 2004	466	7.94	200	240
	October 2005	**405**	**8.4**	**160**	**220**

Invertebrate Taxa

The Main Fork of Box Canyon had 23 taxa and 29,994 organisms per square meter (Table 3, Appendices A-E). The number of taxa was one less than in 2004, but eight more than in 2003. The density estimate had decreased by 18% when compared to 2004 but was over 9,000 higher than the density in 2003. Both ostracod and chironomid density declined to near 2003 levels, but ceratopogonid, Plecoptera, and copepod densities increased. The continued increase in Plecoptera supports a role of increased flow with the ending of the extended drought.

Three of the four East Fork of Box Canyon stations showed a decrease in the number of taxa in 2005. The only station showing an increase was Station 1 which increased from 15 to 17 taxa. Station 2 fell from 17 taxa in 2004 to 12 taxa in 2005. Station 3 fell from 18 taxa in 2004 to 13 in 2005. Station 4 dropped from 18 taxa in 2004 to 16 in 2005. The average for the four sites was 14.5 taxa compared to an average of 17 per station in 2004 and 11 per station in 2003. This is still lower than the 23 taxa found in the Main Fork station in 2005 and the 24 taxa in 2004. None of the East Fork of Box Canyon sites had over 17 taxa. The Main Fork of Box Canyon remained about the same as in 2004 having about eight or nine more taxa than the East Fork Box Canyon stations. The higher sand embeddedness of the East Fork of Box Canyon riffles should constrain those stations to fewer taxa than would be found in the Main Fork of Box Canyon samples, and this factor likely explains the differences between the two streams.

The four sites in the East Fork of Box Canyon had total densities of 17,068, 9,292, 19,907, and 12,514. The invertebrate density at Station 1 approximately tripled from 5585 per square meter in 2004. Site 2 densities fell by 23% from 12,090 per square meter in 2004. Site 3 increased in density by 2.5 fold over 2004, and Site 4 fell by about 30% from 17,655 in 2004. The increase in densities and number of taxa in East Fork of Box Canyon Station 1 indicates that the impact that affected the station in 2004 was transient and that the station has recovered. The situation in Station 2, however, does not appear to have improved. This station is subject to a stream-side slump, and it may affect the stream channel for an extended period of time

The Main Fork of Box Canyon had a strong increase in both *Baetis* and plecopterans, both of which may reflect higher stream flows during the year. Chironomid numbers stayed about the same slightly over 50% of the total invertebrate density. But ceratopogonid larvae increased significantly in density from 347 per square meter in 2004 to 1,141 per square meter in 2005. Copepods also increased in numbers from 0 in 2004 to 3,030 per square meter in 2005. Oligochaetes increased slightly but appear to be fluctuating within the long-term range for that taxonomic group.

Chironomids comprised just 2 to 4% of the total density in the East Fork of Box Canyon in 2005, while in 2004, they made up 23%, 48%, 44%, and 55% of the total organisms at Station 1 through 4, respectively. Chironomids were, therefore, no longer the dominant taxon. Instead *Baetis*, oligochaetes, and early instar plecopterans dominated. Oligochaetes prefer sand substrates, while stoneflies need oxygenated interstitial spaces within the substrate, and *Baetis* requires flowing water. It is not clear why the chironomids decreased in density in the four stations unless the increase in these other groups reduced the resources available to the midge larvae. Since the chironomids (midges) were only taken to the family level in this study, it is not possible to determine either the diversity or the food habits of the midge community.

Baetis mayfly nymphs at Station 1, in the East Fork of Box Canyon had clearly rebounded from the 2004 conditions indicating that the decline seen in 2004 was likely transitory. Densities also increased at Sites 2 and 3, although Site 4 had densities only one-sixth of the 2003 level. Simuliids remained at low densities in 2005. The reason for this is not clear. This group requires flowing water to provide food, and it also requires solid substrates onto which it can attach. It is possible that increased discharge has reduced the amount of organic material in transport during low flow periods which would reduce the available food. It is also possible that the riffles are more embedded in sand (which would be reflected in the increase in oligochaetes), and that would reduce the available substrate to which the simuliids could attach. Increased sand in transport would also be detrimental to the filter feeders. Hydropsychids which occurred in greatest abundance at Site 3 (1,353/square meter) and in much lower numbers in Sites 1 and 2 (30 and 172 per square meter, respectively) in 2003, were absent in the 2004 samples, and were still absent in 2005.

Table 3. Summary of densities per square meter and total taxa for Box Canyon, 2003-2004.

	Main Fork Box Canyon			East Fork Box Canyon Site 1			East Fork Box Canyon Site 2			East Fork Box Canyon Site 3			East Fork Box Canyon Site 4		
	Fall 2003	Fall 2004	**Fall 2005**	Fall 2003	Fall 2004	**Fall 2005**	Fall 2003	Fall 2004	**Fall 2005**	Fall 2003	Fall 2004	**Fall 2005**	Fall 2003	Fall 2004	**Fall 2005**
Ephemeroptera: *Baetis*	20	20	**939**	3313	364	**10029**	2010	1949	**5181**	2242		**2555**	3333	1828	**525**
Ephemeroptera: *Cinygmula*			**40**			**40**								20	
Ephemeroptera: early instar								313							
Plecoptera: *Alloperla*					20			162							
Plecoptera: early instar		646	**6818**	414	2212	**1020**	1353	1919	**1111**	51	323	**2394**		1879	**5808**
Plecoptera: *Hesperoperla pacifica*											10				
Plecoptera: *Malenka californica*	10				61			51		798	949		444	414	
Plecoptera: *Paraperla*	191	10								2515			1485		
Plecoptera: *Zapada*		10	**152**	152	152	**273**	172	374	**525**	61	293	**1252**			**848**
Trichoptera: *Brachycentrus*				10			10								
Trichoptera: *Dicosmoecus*	263												10		
Trichoptera: Early Instar			**20**												
Trichoptera: *Hesperophylax*		202	**293**		91			10	**20**		91	**192**		40	**242**
Trichoptera: *Hydropsyche*				30			172			1353					
Trichoptera: *Lepidostoma*								10							
Trichoptera: *Limnephilus*							10								
Trichoptera: *Neothremma alicia*		10													
Trichoptera: *Oligophlebodes*									**71**						
Trichoptera: *Psychomyia flavida*				10			646								

Trichoptera: pupae		10	**10**												
Trichoptera: *Rhyacophila*						**20**			**10**	20		**30**			**10**
Coleoptera: Dryopidae Helichus			**121**												**10**
Coleoptera: Dytiscidae (larvae)		293	**121**					10						20	**10**
Coleoptera: Dytiscidae (adult)					20										
Coleoptera: *Helichus*		111													
Coleoptera: *Heterlimnius* (larvae)	10	1131			10						10				**1515**
Coleoptera: *Heterlimnius* (adult)	20	10													
Coleoptera: *Hydrophilidae*			**10**												
Coleoptera: *Optioservus* (larvae)		51													
Coleoptera: *Optioservus* (adult)	525														
Diptera: *Atherix*		20													
Diptera: *Caloparyphus*			**10**					10							
Diptera: Ceratopogonidae	10	374	**1141**				40						10		**10**
Diptera: *Chelifera*				30			61							10	
Diptera: Chironomidae (larvae)	16089	18544	**15100**	2636	1293	**333**	2656	5787	**323**	2030	3394	**768**	1182	9292	**253**
Diptera: Chironomidae (pupae)	10	20	**10**		303		40				40	**10**	40	434	
Diptera: *Dicranota*		71	**111**		20	**61**		111	**51**		91	**101**		475	**222**
Diptera: *Dixa*		10		10				10							
Diptera: *Hexatoma*		10				**10**									
Diptera: *Limnophora*											10			20	
Diptera: *Limnophila*		20	**10**			**616**			**303**		10	**364**			**20**
Diptera: *Pedicia*		20									10			30	

Diptera: *Pericoma*	10		**20**		61		10	40			20	**30**	10	10	
Diptera: *Ptychoptera*						**10**									
Diptera: Nr. Rhabdomastix						**10**									
Diptera: Scleroprocta tetonica		10				**20**									
Diptera: *Simulium* (pupae)									**10**			**20**			
Diptera: *Simulium* (larvae)			**10**	1010	40	**182**	5848	343	**172**	1889	20	**444**	1000	808	**81**
Diptera: *Tipula*	61	20	**20**	91	30	**10**	232	343		71	323	**10**	91	394	**30**
Crustacea: Copepoda	303		**3030**	535	303					0	606			303	
Crustacea: Ostracoda	1687	12686	**919**		303	**313**			**10**		616	**313**	10	1212	
Arachnida: Hydracarina	20	1525	**10**				10	303			303				**303**
Mollusca: *Sphaerium*	30	91	**30**												
Annelida: Haplotaxidae						**20**									
Annelida: Oligochaeta	1303	636	**869**		303	**2929**			**1353**	606	576	**9858**	1343	434	**2475**
Planaria		10	**40**			**1172**		30	**152**		10	**1566**		20	**152**
Collembola			**30**					10						10	
Culicidae			**30**												
Hemiptera	71														
Nematoda								303							
Total	20633	36572	**29914**	8242	5585	**17068**	13271	12090	**9292**	11635	7706	**19907**	8959	17655	**12514**
Total taxa	15	24	**23**	12	15	**17**	14	17	**12**	11	18	**13**	11	18	**16**

Biomass

Biomass in the Main Fork of Box Canyon (Table 4) greatly increased over the 2004 level and was over double the 2003 measurement. Station 1 of the East Fork of Box Canyon had almost a 50% decrease in biomass, and Station 2 fell by 25%. The other two sites had substantial increases in biomass. The decline in biomass in Stations 1 and 2 were likely tied to the reduced density of early instar plecopterans, while in Stations 3 and 4, the early instar plecopterans increased. It appears that high fluctuations in biomass can be expected, since the Main Fork samples show a great amount of variability.

Table 4. Biomass comparisons for October 2003-October 2005

Box Canyon Fall 2005 Biomass		**Total**	**g/m²**
Main Fork Box Canyon	October 2003	2.389 g	24.12 g/m²
	October 2004	1.0956 g	11.07 g/m²
	October 2005	**5.571 g**	**56.27 g/m²**
East Fork Box Canyon Site 1	October 2003	0.3501 g	3.54 g/m²
	October 2004	1.5875 g	16.03 g/m²
	October 2005	**0.6698 g**	**6.7650 g/m²**
East Fork Box Canyon Site 2	October 2003	1.4155 g	14.30 g/m²
	October 2004	0.6069 g	6.13 g/m²
	October 2005	**0.4448 g**	**4.4925 g/m²**
East Fork Box Canyon Site 3	October 2003	0.8783 g	8.87 g/m²
	October 2004	0.6974 g	7.04 g/m²
	October 2005	**1.571 g**	**15.867 g/m²**
East Fork Box Canyon Site 4	October 2003	1.3809 g	13.95 g/m²
	October 2004	2.3028 g	23.26 g/m²
	October 2005	**2.8336 g**	**28.619 g/m²**

Diversity Indices

In 2005, the number of taxa in the Main Fork of Box Canyon decreased by one, but the diversity of that station increased from 1.237 to 1.325 (Table 5). This is the result of the numbers of organisms within several of the taxa being more evenly distributed. Site 4 of the East Fork of Box Canyon also had an increase in its diversity value slightly higher than its 2003 reading. However, Stations 1 through 3 had diversity values in 2005 that were lower than in 2004. In 2004, Stations 2 and 3 had reduced diversity relative to the 2003 readings, so these two stations have undergone a continual decline in diversity. This decrease could be caused by a number of factors. One is the shift of the region out of a prolonged drought. The change in precipitation would increase the transport of sediments in the channel and that would in turn change sedimentation dynamics within the stream channel (as was discussed with the simuliids above). Another factor could be subsidence induced changes. Unfortunately, the coincidence of the termination of the drought with the subsidence confounds the data so that no simple conclusion can be made about cause and effect. Filter feeders, simuliids and hydropsychids, both decreased in density in 2004, and they had not recovered in the 2005 sampling period. Both Sites 1 and 2 had the lowest diversity values in 2005, while Site 2 had the lowest diversity value in 2004. This indicates that these two sites continue to be the most heavily impacted, but Site 3 is also showing indications of stress. Station 4 was, according to the diversity index, doing as well in 2005 as it was in the pre-subsidence sampling in 2003.

Table 5. Diversity indices based on natural logs for Box Canyon, October 2003-October 2005

	Main Fork Box Canyon	East Fork Box Canyon Site 1	East Fork Box Canyon Site 2	East Fork Box Canyon Site 3	East Fork Box Canyon Site 4
Oct 2003	0.897	1.505	1.614	1.929	1.713
Oct 2004	1.237	2.059	1.337	1.852	1.553
Oct 2005	**1.325**	**1.278**	**1.280**	**1.509**	**1.881**

Biotic Condition Index

The actual Community Tolerance Quotient (CTQa) was determined from the presence-absence of taxa (Table 6). The individual taxa are assigned a tolerance quotient value which is lower for those taxa that require high water quality (Winget and Mangum 1979). The CTQa is simply the mean of the individual tolerance quotients for the taxa at a given site. Thus, the lower the CTQa value, the better the water quality. The lowest CTQa value for the 2005 samples was the East Fork of Box Canyon Site 1 which had a CTQa value of 70.29. The next lowest was Site 3 with a CTQa value f 70.92, followed by Site 2 with a CTQa of 72.83, and Site 4 with a CTQa of 76.75. The Main Fork of Box Canyon had the highest CTQa, 81.70. The Main Fork Site is very different from the East Fork stations, and its high stress rating is supported by the low diversity that station has had since sampling began in 2003 (Table 5). Within the East Fork of Box Canyon, Site 4, the upstream-most site, is the most stressed, while the downstream-most site in that same drainage is the least stressed (has the fewest stress indicator taxa). These values are opposite of what the diversity indices (Table 5) show, where the upstream-most site, Station 4, has the highest diversity and the downstream-most station, Site 1, has the lowest diversity. The discrepancy reflects the difference between an approach that weighs each taxon equally (the CTQa method) with one that considers the relative abundances of each taxon. The limitations of the CTQa approach has been discussed in previous reports.

Table 6. Tolerance quotients for Box Canyon, Fall 2005

Box Canyon Tolerance Quotients	Main Fork Box Canyon	East Fork Box Canyon Site 1	East Fork Box Canyon Site 2	East Fork Box Canyon Site 3	East Fork Box Canyon Site 4	Ideal Stream
Ephemeroptera: Baetidae: *Baetis spp.*	72	72	72	72	72	72
Ephemeroptera: Heptageniidae: *Cinygmula*	21	21				21
Plecoptera: Chloroperlidae: *Alloperla*						24
Plecoptera: Chloroperlidae: *Paraperla*						24
Plecoptera: Nemouridae: *Malenka californica*						36
Plecoptera: Nemouridae: *Zapada*	16	16	16	16	16	16
Plecoptera: Perlidae: *Hepseroperla pacifica*						18
Trichoptera: Brachycentridae: *Brachycentrus*						24
Trichoptera: Hydropsychidae: *Hydropsyche*						108
Trichoptera: Lepidostomatidae: *Lepidostoma*						18
Trichoptera: Limnephilidae: *Dicosmoecus*						24
Trichoptera: Limnephilidae: Hesperophylax	108		108	108	108	108
Trichoptera: Limnephilidae: *Limnephilus*						108
Trichoptera: Psychomyidae: *Psychomyia*						108
Trichoptera: Rhyacophilidae: *Rhyacophila*		18	18	18	18	18
Trichoptera: Uenoidae: Neothremma alicia						8
Trichoptera: Uenoidae: *Oligophlebodes*			24			24
Coleoptera: Dryopidae: *Helichus*	54				54	54
Coleoptera: Dytiscidae	72				72	72
Coleoptera: Elmidae: *Heterlimnius*					108	108
Coleoptera: Hydrophilidae	72					72
Coleoptera: Elmidae: *Optioservus*						108
Diptera: Athericidae: *Atherix*						24
Diptera: Ceratopogonidae	108				108	108
Diptera: Chironomidae	108	108	108	108	108	108
Diptera: Dixidae: *Dixa*						108
Diptera: Empimidae: *Chelifera*						108
Diptera: Muscidae: *Limnophora*						108

Diptera: Psychodidae: *Pericoma*	36			36		36
Dipter: Ptychopteridae: *Ptychoptera*		108				108
Diptera: Simuliidae: *Simulium*	108	108	108	108	108	108
Diptera: Stratiomyidae: *Caloparyphus*	108					108
Diptera: Tipulidae: *Dicranota*	24	24	24	24	24	24
Diptera: Tipulidae: *Hexatoma*		36				36
Diptera: Tipulidae: *Limnophila*	72	72	72	72	72	72
Diptera: Tipulidae: *Pedicia*						72
Diptera: Tipulidae: *Nr. Rhabdomastix*		72				72
Diptera: Tipulidae: *Scleroprocta tetonica*		72				72
Diptera: Tipulidae: *Tipula*	36	36		36	36	36
Copepoda	108					108
Ostracoda	108	108	108	108		108
Acari: Hydracarina	108				108	108
Mollusca: Gastropoda: *Sphaerium*	108					108
Tricladida: Planariidae	108	108	108	108	108	108
Annelida: Haplotaxidae		108				108
Annelida: Oligochaeta	108	108	108	108	108	108
Collembola	108					108
Culicidae	108					108
Nematoda						108
Total	**1879**	**1195**	**874**	**922**	**1228**	**3561**
n	**23**	**17**	**12**	**13**	**16**	**49**
CTQa	**81.696**	**70.294**	**72.833**	**70.923**	**76.75**	**72.7**

<u>Community Tolerance Quotient and Biotic Condition Indices</u>

The CTQa index can be adjusted to a valuse that has been corrected for various physical factors associated with the stream system. The adjustment is made with a predicted community tolerance quotient (CTQp). The CTQp values are estimated from a combination of gradient, substrate, and water chemistry in accordance with a key provided by Winget and Mangum (1979). One of the chemical factors that is important, sulfate, was not measured in this study, so it must be estimated (see Shiozawa 2004). The estimates in 2005 were again 40 mg/l for the East Fork of Box Canyon and 80 mg/l for the Main Fork of Box Canyon. The gradients of both sites, estimated from topographical maps, are less than 1.2%. The Main Fork of Box Canyon was a gravel-rubble substrate, while the stations on the East Fork were sorted gravels or rubble substrates. The estimated CTQp for the Main Fork of Box Canyon was 51, while the East Fork Stations had a CTQp of 53.

The Biotic Condition Index is the ratio of CTQp/CTQa expressed as a percent. This ratio effectively reverses the reading of the relationships so that instead of low values being indicative of higher quality waters, high BCI values indicate better water quality. The ideal is a BCI of 100 or higher, meaning that the station meets or exceeds the predicted level. The BCI for 2005 in the Main Fork of Box Canyon (Table 7) was 62.42, down from 2004, but very close to the three-year average. This station does not meet the ideal predicted by the physical parameters used by Winget and Mangum (1979). The BCI of the Main Fork of Box Canyon decreased by about 10% from the 2004 level. It had increased by about 10% from 2003 to 2004. The BCI in the East Fork of Box Canyon (Table 7) ranged from 69 to 75. In 2004, these sites ranged from 67-76. The average BCI for the four East Fork sites in 2003 was 71.5. In 2004, that average was 72.5, and in 2005, it was 72.4. This suggests that the BCI of the East Fork has not changed since the subsidence following the 2003 sampling.

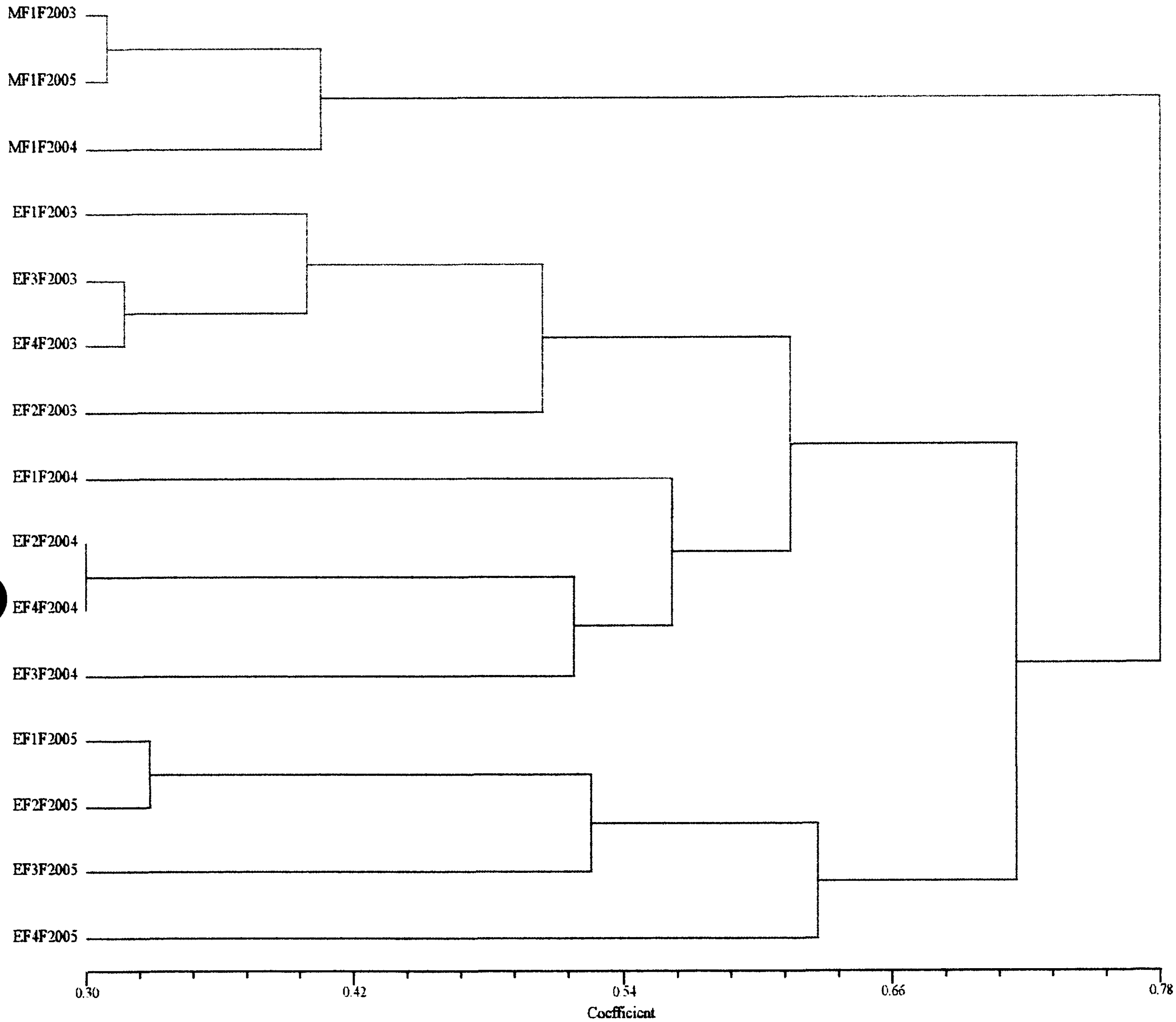
Table 7. CTQa and BCI values for Box Canyon, October 2003-October 2004

	Main Fork	East Fork Site 1	East Fork Site 2	East Fork Site 3	East Fork Site 4
	CTQa/BCI	CTQa/BCI	CTQa/BCI	CTQa/BCI	CTQa/BCI
October 2003	84.8/ 60.14	78.33/ 67.66	85.57/ 61.94	60.91/ 87.01	76.36/ 69.41
October 2004	73.62/ 69.27	69.25/ 76.53	70.7/ 74.96	75.05/ 70.62	78.16/ 67.81
October 2005	**81.70/ 62.42**	**70.29/ 75.4**	**72.83/ 72.77**	**70.92/ 74.73**	**76.75/ 69.06**
Average	80.04/ 63.94	72.62/ 73.19	76.37/ 69.89	68.96/ 77.45	77.09/ 68.76

Cluster Analysis

The data were run in a cluster analysis using the Bray-Curtis dissimilarity index (Poole 1974, Krebs 1989) with the unweighted pairs group averaging algorithm (UPGMA) (NTSYS; Rolf 2000). The analysis (Figure 1) resulted in two main clusters separating at a dissimilarity level of 0.78. One cluster consisted of all three years of the Main Fork of Box Canyon samples. The other included all of the East Fork of Box Canyon samples. Within the East Fork of Box Canyon cluster, the sites were clustered by year. The 2003 and 2004 samples formed one subcluster, and the 2005 samples formed a second subcluster. These two subclusters separated at a dissimilarity level of approximately 0.72. The 2003 and 2004 samples separated from one another at a dissimilarity level of about 0.62. This indicates that the 2005 invertebrate communities in the East Fork of Box Canyon are quite divergent from the communities samples in 2003 and 2004. The upstream-most site, Station 4, is more divergent from the other 2005 East Fork Box Canyon sample sites than were the 2003 stations from the 2004 stations. The East Fork of Box Canyon stations are still diverging from their state in 2003. We can conclude from the cluster analysis that the community structure in 2005 was continuing to shift away from the pre-subsidence conditions. As with earlier analyses above, the cause of this shift could be either subsidence or the recovery of the area from the extended drought. It is not clear which is the primary factor.

Figure 1. Cluster dendrogram for the Box Canyon samples



CONCLUSIONS

The Main Fork of Box Canyon differs significantly from the East Fork of Box Canyon. That difference was clear in the 2003 sampling and has remained through the 2004 and 2005 sampling periods. As was noted in previous reports, the difference between the two forks of Box Canyon limits the use of the Main Fork of Box Canyon site assessing annual trends in the region. Changes in the invertebrate community and water chemistry of the Main Fork of Box Canyon site between 2003, 2004, and 2005 still indicate an increase in stream discharge. A similar discharge increase would have occurred in the East Fork of Box Canyon. That may have increased transport of sand which had accumulated in the channel during the drought. Alkalinity and hardness in the East Fork of Box Canyon increased in 2004 and remained high in 2005. The 2005 conductivity readings in all stations were much higher than in 2003.

The cluster analysis reinforces the difference between the Main Fork of Box Canyon and the East Fork sites. All three years of samples from the Main Fork of Box Canyon clustered together. The 2005 sample set was most similar to the 2003 sample set (dissimilarity about 0.31). The 2004 sample set then joined the 2003-2005 synthetic stand at a dissimilarity of 0.40. Cluster analysis also illustrates a general trend within the East Fork of Box Canyon. The East Fork of Box Canyon samples cluster by year with the 2005 samples being the most divergent of the series. The separation between the 2003 and 2004 clusters of the East Fork of Box Canyon occurred at approximately 0.60 dissimilarity, while the 2005 samples from the East Fork of Box Canyon separated at a dissimilarity value of 0.72. This indicates that the East Fork of Box Canyon is undergoing a change in community composition. The change is not just induced by the discharge related differences seen between the 2003 and 2004/2005 Main Fork Box Canyon samples, since the Main Fork of Box Canyon samples returned toward the 2003 community structure. The increasing dissimilarity between years in the East Fork of Box Canyon suggests that the differences in the East Fork sites are more complex. The CTQa and BCI values indicated that while the Main Fork site had improved in quality between 2003 and 2004, it had regressed in condition (as indicated by the BCI) in 2005 being close to the 2003 BCI value. This relationship is reiterated in the cluster analysis where the 2003 and 2005 samples cluster together with a lower dissimilarity that the 2004 Main Fork samples. The East Fork stations again showed no concerted change with the BCI. The differences in the BCI values appear to reflect an inherent variability among stations.

In 2004, all stations in both forks of Box Canyon had an increase in the number of taxa, but in 2005, the increase only continued in the Main Fork of Box Canyon and Station 1 of the East Fork of Box Canyon. The other sites had decreases in the number of taxa. The densities of invertebrates in the East Fork of Box Canyon only increased in Stations 1 and 3. The increase in Station 1 was driven by high numbers of *Baetis,* while the increase in Station 3 was driven mainly by high numbers of oligochaetes. The increased oligochaetes likely reflect an increase in sand (Jordan et al. 1999). Biomass increased in three sample locations and declined in two stations, the East Fork of Box Canyon Stations 1 and 2. Diversity in the East Fork of Box Canyon increased at one site, Site 4, but decreased at all other sites. Diversity in the Main Fork of Box Canyon increased slightly in 2005. Filter feeding invertebrates were greatly reduced in all stations in the East Fork of Box Canyon. The increase in oligochaetes suggests a higher proportion of the sampled area was embedded in sand, possibly a result of either increased flows bringing more sand into the system or subsidence induced changes have mobilized more sand substrates. As with the previous reports, a number of potential causal factors exist, and they likely cannot be separated. The impacts of the subsidence and mitigation are confounded with the conditions established by the prolonged drought and its termination in 2004.

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Appendix A. Sample data Main Fork Box Canyon, Fall 2005

Box Canyon Main Fork Fall 2005		Site 1	Site 2	Site 3	Density
Ephemeroptera	*Baetis sp.*	1	62	30	939.3
	Cinygmula sp.	0	2	2	40.4
Plecoptera	Early instar Plecoptera	44	141	490	6817.5
	Zapada	0	15	0	151.5
Trichoptera	Tricoptera pupae	1	0	0	10.1
	Tricoptera Early Instar	2	0	0	20.2
	Hesperophylax	16	9	4	292.9
Coeleoptera	Dytiscidae	8	0	4	121.2
	Hydrophilidae	1	0	0	10.1
	Drypidae Helichus	8	0	4	121.2
Diptera	*Caloparyphus* (Stratiomyideae)	1	0	0	10.1
	Ceratopogonidae	83	0	30	1141.3
	Chironomidae (larvae)	1015	3	477	15099.5
	Chironomidae (pupae)	1	0	0	10.1
	Dicranota (Tipulidae)	1	1	9	111.1
	Limnophila	0	0	1	10.1
	Pericoma (Psychodidae)	0	1	1	20.2
	Simulium (Simulidae)	0	1	0	10.1
	Tipula sp. (Tipulidae)	1	0	1	20.2
Crustacea	Copepoda	270	0	30	3030
	Ostracoda	1	0	90	919.1
Arachnida	Hydracarina	0	0	1	10.1
Mollusca	*Sphaerium sp.*	3	0	0	30.3
Annelida	Oligochaeta	5	81	0	868.6
Misc.	Collembola	0	0	3	30.3
	Culicidae	3	0	0	30.3
	Planaridae	0	3	1	40.4
	Totals	*1465*	*319*	*1178*	**29916.2**

Appendix B. Sample data East Fork Box Canyon Site 1, Fall 2005

Box Canyon Fork Site 1 Fall 2005		Site 1	Site 2	Site 3	Density
Ephemeroptera	*Baetis sp.*	407	307	279	10029.3
	Cinygmula sp.	0	0	4	40.4
Plecoptera	Early instar Plecoptera	96	2	3	1020.1
	Zapada	5	14	8	272.7
Trichoptera	*Rhyacophila* (larvae)	1	0	1	20.2
Diptera	Chironomidae (larvae)	2	0	31	333.3
	Dicranota (Tipulidae)	3	3	0	60.6
	Hexatoma	0	1	0	10.1
	Limnophila	0	60	1	616.1
	Haplotaxidae	0	0	2	20.2
	Scleroprocta Tetonies	0	1	1	20.2
	Ptychoptera (Ptychopteridae)	0	1	0	10.1
	Simulium (Simulidae)	7	2	9	181.8
	Tipula sp. (Tipulidae)	0	0	1	10.1
	NR. Rhabdomastix	0	0	1	10.1
Crustacea	Ostracoda	1	0	30	313.1
Annelida	Oligochaeta	178	36	76	2929
Misc.	Planaridae	9	71	36	1171.6
	Totals	*709*	*498*	*483*	**17069**

Appendix C. Sample data East Fork Box Canyon Site 2, Fall 2005

Box Canyon Fork Site 2 Fall 2005		Site 1	Site 2	Site 3	Density
Ephemeroptera	*Baetis sp.*	4	323	186	5181.3
Plecoptera	Early instar Plecoptera	32	65	13	1111
	Zapada	8	19	25	525.2
Trichoptera	*Hesperophylax*	2	0	0	20.2
	Oligophlebodes	7	0	0	70.7
	Rhyacophila (larvae)	0	0	1	10.1
Diptera	Chironomidae (larvae)	0	32	0	323.2
	Dicranota (Tipulidae)	0	2	3	50.5
	Limnophila	0	30	0	303
	Simulium (Simulidae) Pupae	0	1	0	10.1
	Simulium (Simulidae)	0	9	8	171.7
Crustacea	Ostracoda	0	0	1	10.1
Annelida	Oligochaeta	37	48	49	1353.4
Misc.	Planaridae	1	10	4	151.5
	Totals	*91*	*539*	*290*	**9292**

Appendix D. Sample Data East Fork Box Canyon Site 3, Fall 2005

Box Canyon Fork Site 3 Fall 2005		Site 1	Site 2	Site 3	Density
Ephemeroptera	*Baetis sp.*	105	74	74	2555.3
Plecoptera	Early instar Plecoptera	76	19	142	2393.7
	Zapada	53	43	28	1252.4
Trichoptera	*Hesperophylax*	6	2	11	191.9
	Rhyacophila (larvae)	1	1	1	30.3
Diptera	Chironomidae (larvae)	10	2	64	767.6
	Chironomidae (pupae)	1	0	0	10.1
	Dicranota (Tipulidae)	5	1	4	101
	Limnophila	1	1	34	363.6
	Pericoma (Psychodidae)	1	1	1	30.3
	Simulium (Simulidae) pupae	1	1	0	20.2
	Simulium (Simulidae)	36	1	7	444.4
	Tipula sp. (Tipulidae)	1	0	0	10.1
Crustacea	Ostracoda	31	0	0	313.1
Annelida	Oligochaeta	124	786	66	9857.6
Misc.	Planaridae	48	37	70	1565.5
	Totals	*500*	*969*	*502*	**19907.1**

Appendix E. Sample data East Fork Box Canyon Site 4, Fall 2005

Box Canyon Fork Site 4 Fall 2005		Site 1	Site 2	Site 3	Density
Ephemeroptera	*Baetis sp.*	47	0	5	525.2
Plecoptera	Early instar Plecoptera	260	238	77	5807.5
	Zapada	31	0	53	848.4
Trichoptera	*Hesperophylax*	11	7	6	242.4
	Rhyacophila (larvae)	1	0	0	10.1
Coeleoptera	Dytiscidae	0	1	0	10.1
	Dryopidae Helichus	0	1	0	10.1
	Heterlimnius (larvae)	0	150	0	1515
Diptera	Ceratopogonidae	0	1	0	10.1
	Chironomidae (larvae)	9	15	1	252.5
	Dicranota (Tipulidae)	6	12	4	222.2
	Limnophila	1	1	0	20.2
	Simulium (Simulidae)	7	0	1	80.8
	Tipula sp. (Tipulidae)	1	0	2	30.3
Arachnida	Hydracarina	0	30	0	303
Annelida	Oligochaeta	33	31	181	2474.5
Misc.	Planaridae	2	1	12	151.5
	Totals	*409*	*488*	*342*	**12513.9**